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IGNITION AND FLAMMABILITY PROPERTIES
OF "FIRE-SAFE FUELS"

W. W. Wimer, et al

Southwest Research Institute

Prepared for:

Army Mobility Equipment Research and
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February 1974

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- (2) Conduct an ignition-limits study of halogenated hydrocarbons (halons), including the influence of bromochloromethane (BCM or halon 1011) on diesel fuel flammability limits.
- (3) Determine the flammability hazards as measured by the AFLRL mist flashback and impact dispersion procedures that were originally developed for assessment of aircraft-fuel crash survivability.

This report describes the results of study items 2 and 3 above.

Background information is provided to illustrate the nature of the experimental problem, and the method and apparatus designed for obtaining flammability limits is described. The apparatus is a closed system with a capability to operate at relatively high temperatures and pressures if such conditions are desired. In essence, the measurement of ignition limits is accomplished by injecting the hydrocarbon and/or halon liquid into an evacuated mixing tank. Air, or mixtures of oxygen and nitrogen, are then added to increase mixing tank pressure to the desired level. Mixing is accomplished by creating "hot spots" at six locations on the 35 liter stainless steel tank. All lines from these mixing tanks to the explosion bomb are electrically heated to prevent dew-point-condensation problems.

All of the experiments reported in this document were conducted at ambient pressure using a high voltage spark plug as the ignition source. The ignition-limits apparatus and procedures were calibrated by measuring the flammability limits of dichloromethane (methylene chloride or halon 1020) at 200°C and ambient pressure. The experimental results with dichloromethane gave reasonable agreement with literature values, and experiments were then conducted with a narrow-cut diesel fuel containing various concentrations of bromochloromethane (halon 1011) at 300°F and ambient pressure. Because the limited scope of this program precluded exploration of temperature and pressure effects upon the influence of bromochloromethane-diesel fuel flammability, the developed data do not provide a broad enough data basis for developing a better understanding of inhibitor mechanisms. However, they provide a first step for developing such a data base.

Impact dispersion data reveal that the peak transient fireball dimensions produced by a high flashpoint DF-2 diesel fuel could be progressively decreased with increasing concentrations of dibromomethane (halon 1002). Impact dispersion and mist flashback experiments conducted with a relatively volatile Arctic diesel fuel indicated that a mixed-halon additive (85%, 10%, and 5% of halons 1011, 1020, and 1002, respectively) did not influence the mist flammability; whereas, AM-1 antimist additive completely overshadowed any effects of the halon additive. None of these experiments involved ground fires; hence, no conclusions relative to the influence of halon additives and/or AM-1, or both, on ground fire flammability characteristics can be made based upon the impact dispersion data. On the other hand, simplified experiments with wicks suggest that the recommended 5% (liquid) concentration of bromochloromethane (halon 1011) may not prevent personnel clothing fires.

It is recommended that consideration be given to the study of various other candidates, including antimist additives, as fire-safe fuel additives.

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INTERIM REPORT
AFLRL NO. 39

by

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prepared by

U. S. Army Fuels and Lubricants Research Laboratory
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San Antonio, Texas

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Coating & Chemical Laboratory
Aberdeen Proving Ground, Maryland

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FOREWORD

This report was prepared at the U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, under DOD Contract No. DAAK02-73-C-0221. The project was administered by the Coating and Chemical Laboratory, U.S. Army Mobility Equipment Research and Development Center, Aberdeen Proving Ground, Maryland 21005, with Mr. C. F. Schwarz serving as project monitor.

The authors wish to acknowledge the assistance of Messrs. J. P. Pierce and J. A. Kachich for the installation, operation and maintenance of the experimental apparatuses. Acknowledgement is also given to Mr. E. C. Owens for his help with the computer-fitting of the transducer calibration data, to Mr. D. C. Babcock for producing the photographs used in this report, and to Mr. F. W. McBryde for the installation and maintenance of the electronic equipment. Special acknowledgement is given to Messrs. H. L. Ammlung, M. E. LePera, F. W. Schaeckel, R. D. Quillian, Jr., and J. T. Gray for their encouragement, comments, and suggestions.

SUMMARY

As part of the coordinated AMC fire-safe fuel research program, the U.S. Army Fuels and Lubricant Research Laboratory, (AFLRL) was instructed to undertake the following:

- (1) Conduct an engine parameter optimization study with the "fire-safe fuel". The results of this study are presented in AFLRL Interim Report No. 31.
- (2) Conduct an ignition-limits study of halogenated hydrocarbons (halons), including the influence of bromochloromethane (BCM or halon 1011) on diesel fuel flammability limits.
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I. INTRODUCTION

Both the mobility and range of Army combat equipment are penalized by the necessity for protecting vital components by the use of armor. If this additional weight could be reduced or eliminated in some or all of the strategic component locations, substantial improvements in both mobility and range could be anticipated. The Terminal Ballistics Laboratory at Ballistics Research Laboratory (BRL, Aberdeen Proving Ground, Maryland) has recommended the use of substantial quantities of halogenated fire extinguishants as part of the fuel formulation to prevent sustained liquid fuel burning following exposure to an ignition situation occurring from ballistic penetration.

The initial recommendation was to use 10 liquid volume percent of dibromomethane in diesel fuel; however, at a later time, the candidate fire-safe fuel (FSF) additive was changed to bromochloromethane (BCM), since this latter compound was alleged to be equally effective at substantially lower liquid volume percent concentrations (5%, rather than 10%). As noted in Reference 5, program input from Coating and Chemical Laboratory (C&CL), Terminal Ballistics Laboratory (TBL), and U.S. Army Fuels and Lubricants Research Laboratory (AFLRL) was collated by C&CL into a coordinated test plan and forwarded to the U.S. Army Tank-Automotive Command (TACOM) who had been assigned the lead laboratory function by AMC Headquarters. As its part of the coordinated FSF Research Program, AFLRL was instructed to undertake the following research:

- (1) Conduct an engine parameter optimization program with the "fire-safe fuel". The results of this program are presented in AFLRL Interim Report No. 31.
- (2) Conduct an ignition-limits study of halogenated hydrocarbons (halons), both with and without the presence of diesel fuel.
- (3) Determine flammability hazards as measured by the AFLRL mist flashback and impact dispersion procedures that were developed for assessment of aircraft fuel crash survivability. It is the purpose of this report to present the results of the aforementioned items (2 and 3) of the AFLRL studies.

II. BACKGROUND

Flammability (or ignition) limits are usually measured by exposing a gas mixture to an intense ignition source, such as an electric spark or pilot flame, in a duct or closed vessel. For such techniques, it has been observed^{(9)*} that the range of flammability limits varies with the orientation of the flame propagation chamber, with the broadest range being obtained for upward propagation of the flame resulting upon ignition. For most volatilizable hydrocarbons, the lower (lean) flammability limit is about 48 mg of fuel per liter of air at 25°C.⁽⁹⁾ This concentration is about 55% of the stoichiometric fuel concentration. At 25°C, the volume fraction fuel concentration at the upper (rich) flammability limit is approximately equal to two-thirds of the square root of the volume fraction fuel concentration at the lower (lean) limit.⁽⁹⁾

At either the lean or rich limit, the energy per unit volume (and time) required to achieve ignition approaches infinity. Hence, measured flammability limits are somewhat dependent upon the apparatus, via the ignition source energy and geometry.

In the case of halogenated hydrocarbons, such as halon extinguishants, the energy requirements to achieve ignition are substantially greater than those for pure hydrocarbons. However, halons, such as those discussed in this report, do undergo combustion under certain conditions. On the other hand, mixtures of hydrocarbons and halons display ignition requirements intermediate between those of pure hydrocarbons and pure halons. In order to evaluate BCM as a flame inhibitor, and also to aid in understanding the mechanisms by which it and other halogenated hydrocarbons inhibit flames, it was desirable to develop basic flammability-limits data hitherto unavailable.

Although there is no ASTM standard for measuring flammability limits, several techniques have been developed in the past, using various types of apparatuses.^(1,2,9,10) The method and apparatus used to obtain the data contained in this report were designed to give the capability of operating at relatively high temperatures and pressures, as well as at ambient conditions, if data under such conditions should be desired.

*Superscript numbers in parentheses refer to the references listed in Section VI of this report.